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**SUBJECT:** A Feasible Planetary Exploration  
Program Through 1980 - Case 710**DATE:** February 26, 1968**FROM:** J. P. Downs  
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TECHNICAL MEMORANDUMINTRODUCTION

In late November and early December of 1967, the authors were asked to develop their point of view toward a/balanced manned and unmanned planetary program through 1980.<sup>a</sup> This paper was prepared in response to that request and represents the authors' thinking at that particular time. The rationale developed in brief form in the following pages is a reflection of a long term point of view. The particular program selected to illustrate this rationale represents an estimate of technical feasibility and one possible allocation of resources. As more information becomes available on technical details and resources, the program may change. However, the rationale expressed in the paper is expected to remain much as it is now.

GENERAL

The planetary program in Figure 1 has three branches. One branch builds on the Mariner flybys of Mars and Venus and uses unmanned orbiters with small survivable landers and atmospheric probes as a precursor to manned exploration. This branch uses the scientific and technological achievements of the unmanned flights to design and guide the planning of a manned exploration program. The second and third branches are aimed toward the scientific exploration of the solar system. These branches are included to provide early knowledge of the rest of the solar system (excluding the sun) to permit rational planning of space exploration in the 80's.<sup>a</sup> The second branch explores Jupiter and the major planets and is, in a sense, the major challenge to the unmanned program. It offers technology a new challenge in systems and reliability and will provide science with new data on the nature and structure of the solar system. The third branch is aimed towards the comets and asteroids and capitalizes on Mariner technology.

The program in Figure 1 is based on a particular rationale of exploration and certain assumptions as to resource availability and management policy. The major assumptions are:

- (1) It is necessary to keep the option of manned planetary exploration in the late 1970's open.

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(2) It is desirable to use industry to build flight hardware for at least the branch leading to manned flights.

(3) It is desirable to keep the scientific and technical expertise developed in the planetary program over the last decade intact.

(4) FY 69 funding will be tight but new starts will be possible for planetary flight programs and the long range NASA annual budget will be between 5 and 6 billion 1967 dollars.

(5) The next major new start of manned hardware will be FY 71 or FY 72.

(6) The types of launch vehicle and major configuration changes in the overall planetary program should be few in number.

An example of the way that these assumptions have influenced the program is that the first manned mission shown is for a 1978 triple planet flyby even though the 1977 triple planet flyby is equally attractive and is also technically achievable.

Four basic launch vehicles appear adequate for planetary exploration through 1980. These include the Atlas, Centaur, the Titan III, and the Saturn V, with possibly some upgrading for manned missions. The exploration of Jupiter and the major planets requires a vehicle with a payload capability at high injection energies beyond the Titan III class. One possibility here is the addition of a Centaur upper stage to the Titan III vehicle. To illustrate the required class of vehicle, performance data from NASA TMX 60153, "Launch Vehicle Estimating Factors," has been used.

Configurations for the spacecraft have not been identified in the text or in Figure 1 for the particular missions, since the amount of funding and the relative weight placed on the above assumptions will dictate this choice. One view of these assumptions would dictate a choice of the Langley little orbiter\*, Ames atmospheric probes, and the JPL survivable Mars impact lander for the main line Mars/Venus program. In this view the current Mariner team would be aimed toward the comet and asteroid missions in the later 1970's, concentrating on Venus/Mercury swingby missions in the early '70's, and a new team would be formed and aimed toward the Jupiter missions.

\*for example, as studied by the Boeing Co.

JPL as  
non-industry  
contractor

in reality it  
was half this

it was -  
but shuttle,  
not planetary

one-year postpone-  
ment caused  
by relaxed  
schedule, but  
get limits

- (1) The topography and morphology of selected areas of the surface from Mariner low and moderate resolution TV.<sup>(2,3)</sup>
- (2) Inferences as to surface color and composition derived from earth-based observations, Mariner low resolution TV (either red or green filtered), and '69 Mariner IR spectroscopy.
- (3) Surface infrared temperatures measured from earth and the '69 Mariner, and radio emission temperatures measured from earth.
- (4) Altitude profiles of atmospheric refractivity (leading to density, pressure, and temperature) and ionospheric electron density at selected locations determined from Mariner radio occultation experiments.
- (5) Some of the constituents of the atmosphere identified through earth-based and '69 Mariner spectroscopy.
- (6) The charged particle and magnetic field properties measured along the trajectory of the Mariner IV flyby spacecraft.<sup>(4)</sup>
- (7) The orbital parameters of the moons of Mars from earth-based observations.
- (8) The dynamical parameters of Mars as determined by earth-based optical and radar techniques.

Major areas of future interest include:

- (1) A search for evidence of existing or fossil life.
- (2) The dynamics, structure and composition (including minor components) of the atmosphere.
- (3) The morphology, bearing strength and composition of the surface, including temporal variations of the wave of darkening and polar caps.
- (4) The structure of the interior and a knowledge of possible seismicity and volcanism.

The exploration of Mars shown in Figure 1 begins with the two 1969 Mariner flybys, and phases into an orbital program using atmospheric and lander probes. This is followed by a series of manned missions.

The 1969 Mariner Mars flyby is the last of the currently funded missions in NASA's planetary program. The spacecraft is an advanced version of the 1964 Mariner Mars spacecraft and uses the Atlas/Centaur as the launch vehicle. The mission payload replaces the '64 particles and fields experiments by IR and UV spectrometry and IR radiometry at Mars. Also, this mission should return a better selection of TV pictures, including both low and

moderate resolution pictures (2 cameras) and several of the full planet disk. Improvements in the communications system, such as use of the 210' Goldstone receiver, will increase the data return capability by about 2 orders of magnitude compared to Mariner IV.

Launch vehicle selection is relatively straightforward for the post '69 unmanned missions if the requirements stated in this Memorandum are accepted. The Atlas/Centaur provides marginal payload capability in Mars and Venus orbit in the early to mid-1970's, and virtually no probe delivery capability. Therefore, the Titan III-C is suggested as the launch vehicle for this program thru 1973. This provides the margin on a Type I trajectory for roughly 300-600 lbs of in-orbit science plus the capacity for at least one atmospheric or survivable impacting lander probe for each of the 1971-1973 Mars and Venus orbital missions shown in Figure 1. Mars 1975 and 1977 flights using a Titan III-C would require Type II trajectories to have an equivalent payload.

Preliminary studies of an orbital spacecraft in the 800 lb class have been carried out by JPL, using a Mariner derivative, and the Boeing Company, using a Lunar Orbiter derivative. The two approaches are quite similar in the possible data return. Both of these studies have assumed three prime objectives for the orbital spacecraft: Mars orbit, Venus orbit, and lunar orbit. The lunar orbit applications will not be discussed here.

The earliest opportunity for an orbiter mission to Mars is 1971, and there is sufficient time to meet this date with some FY 68 funding for long lead items and accelerated FY 69 funding. The lack of funding prior to FY 70 would probably dictate a spare parts mission in 1971. A Titan-based program would allow ample capability for a probe, and the type recommended is the survivable surface impactor under development at JPL.<sup>(3)</sup> In its nominal design this probe weighs about 350 lbs including an instrumented entry shell, lander probe encased in balsa wood, and parachute system. The lander would impact Mars at about 100 feet/sec in a 5 millibar atmosphere. About 13 pounds of scientific instrumentation can be landed in this manner. The instrumented entry shell measures thermodynamic properties of the atmosphere during descent. An "orbiter only" mission to Mars in 1971 is available using the Atlas/Centaur. The scientific payload for this mission using the Boeing numbers is approximately 200 lbs.

The scientific payload of this first orbiter should continue the attack on the major scientific questions about the planet. This mission should establish a strategy for exploration by the next three orbiter/probe missions, which in turn should establish the strategy for the manned flyby missions.



A significant experiment to carry out in orbit would be optical imagery of the surface using a vidicon system with color filters. Although this would not achieve the resolution of a photo subsystem, it would provide a color time history of the wave of darkening over a large fraction of the planet surface. A supplemental infrared map of the surface emission temperature would also be of interest. Repeating the radio wave occultation experiment during a nominal 6-month mission duration would determine profiles of atmospheric pressure and ionospheric electron density at hundreds of points around the planet.

The instrumented entry shell of the survivable surface impactor would record selected thermodynamic properties along a vertical profile in the atmosphere. These data will affect the targeting and guidance strategy of more sophisticated lander probes launched from subsequent manned reconnaissance and retrieval missions or larger follow-on unmanned probes. Analysis of data from this first flight should determine whether there is a requirement for a later orbiter mission with multiple atmospheric probes. The plan shown in Figure 1 would deliver five instrumented entry shells on what are primarily lander probe missions.

The lander probe should have a lifetime of several days. It would be interesting to try a life detection experiment on the 1971 mission, and a gas chromatograph is a good candidate since it detects atmospheric gas components as well as surface organic substances of biologic interest. Pressure and temperature variations during a diurnal cycle and an initial soil mechanics experiment would also be of interest and within the capability of such a lander.

The 1973 opportunity is probably the last chance for an orbiter/probe mission to Mars using a Titan III-C launch vehicle on a Type I trajectory until after 1977. Based on an analysis of 1971 mission data, two spacecraft could be launched in 1973 with the objective of delivering impacting landers to different areas. A vidicon system with color filters would again be the prime orbital experiment. In addition to the Mars surface, Phobos and Deimos would make interesting photographic subjects. The periapsis points of the two spacecraft orbits would be selected at different locations to provide increased TV coverage of the surface.

The prime objective of the lander mission would again be life detection. Assuming the earlier gas chromatography experiment worked, emphasis could now be devoted to exobiology. A reasonable experiment might be one which detects metabolism and growth of micro-organisms. Pressure, temperature, and soil mechanics experiments could also be repeated.

By 1975 technological advancements in photosystems (e.g., dielectric tape cameras) should be available. Improvements in the telecommunication subsystem (e.g., foldable antennas with increased aperture areas) should supply the capacity to support an increased bit rate, making high resolution photographic coverage of the surface feasible. Tracking and atmospheric density data from the 1971 and 1973 missions should allow a lower periapsis altitude for subsequent missions, and sterilized orbital spacecraft may also be adopted. The emphasis of surface imagery should shift from low resolution color aspects to higher resolution topography and morphology. Site selection for subsequent soft landers is a major objective. These system improvements and associated requirements would lead to a larger orbital vehicle for the 1975 and 1977 than for the 1973 mission.

The atmospheric entry angle of the lander probe may be selected to provide specific data for later, more sophisticated probes. The experiment payload of the entry shell may also be changed from that on the 1971 and 1973 missions. The lander probe itself could be targeted to a specific area on the surface based on earlier imagery. The prime experiment objective would be exobiology, with the particular instrumentation to be determined.

1977 represents the final precursory site survey opportunity. Emphasis would be focused on particular sites of interest for sample collection. Possible innovations in the orbiter photo subsystem might include color filters. A facsimile scan system on the lander would provide small scale topography of a potential landing site and the first information on surface micro-relief.

The larger orbiter and landers coupled with the increased energy requirements of the 1975 and 1977 missions appear to require a launch vehicle intermediate between the Titan III-C and the Saturn V. However, uncertainty in mission requirements and the possibility of delays in obtaining the larger payload class of orbiters and probes leave the launch vehicle and spacecraft for these missions as open questions at this time.

In late 1979 the first manned flyby mission shown in Figure 1 would reach Mars. The prime objective is the recovery of a sample from the Mars surface for life detection experiments. (6) A secondary objective is the establishment of geophysical stations on the Mars surface. Both objectives can be met by soft landing probes. The former objective requires a probe capable of returning to the manned vehicle. The returned samples will be examined for life forms and

pathogenicity on board the manned spacecraft before being returned to earth for more detailed analysis. High resolution telescopic photography from the manned vehicle during periapsis passage can provide surface detail to a level of approximately ten meters.

The objectives of the 1981 manned flyby mission are sample return and site survey. The nature of the site survey will depend on whether the 1984-5 mission is planned as a manned lander or orbiter. The decision on this would probably be made before the first manned flyby mission left earth. If the question of life on Mars could be settled before a manned landing attempt, the prior knowledge of the forward and back contamination problems would reduce the complexity and weight of the manned landing system.

#### VENUS

The present knowledge of the planet Venus consists roughly of the following:

- (1) A trace through the particle and magnetic field environment above the planet atmosphere as observed by Mariners II and V<sup>(7)</sup> and the Russian Venus 4 orbital probe.<sup>(8)</sup>
- (2) Infrared temperatures (probably at the top of the clouds) and microwave temperatures (probably at the surface) from both Mariner II and earth-based measurements.
- (3) Major atmospheric constituents and a profile of pressure and temperature below 26 km at one point on the night side, from the Venus 4 lander probe.<sup>(8)</sup>
- (4) Altitude profiles of atmospheric refractivity (leading to density, pressure, and temperature) and ionospheric electron density at two locations determined from the Mariner V radio occultation experiments.
- (5) The density of hydrogen in the outer atmosphere (Mariner V) and the identification of selected components of the lower atmosphere (earth-based spectroscopy).
- (6) Dynamical parameters of Venus as determined by earth-based optical and radar techniques.

The U. S. program has been confined to remote sensing from flyby spacecraft and earth. Neither the U. S. nor the Russians have photographed Venus from a space probe.

The major areas of future interest include:

- (1) Life detection at Venus, either in the atmosphere or conceivably at high surface elevations where the temperature would be lower than average.

- (2) Composition of the clouds.
- (3) Circulation of the atmosphere.
- (4) Surface topography and morphology.
- (5) Internal structure and composition.

Optical imagery has proved to be one of the most informative types of data in the exploration of Mars and the moon. It is costly data because of the required communication bandwidth, which is at a premium on a planetary mission. Assuming that optical imagery of Venus will be an objective of the ~~present~~ program in the early to mid-1970's, it should be decided as soon as possible whether the imagery should be acquired via a vidicon or a photo subsystem. If Venus is completely covered by clouds at all times, a low resolution vidicon system should suffice to do a job similar to that of Tiros on earth. This could be a fairly adaptive system with a photo cell to adjust the vidicon iris, probably requiring little precursory information on cloud albedo, etc. If, however, the surface is visible through the clouds, a high resolution photographic system will probably be called for. The design and operation of this system will be more straightforward if detailed precursory data on atmospheric and surface light levels are available. A mission which will return TV pictures is desirable as soon as possible in order to make the necessary decisions bearing on the requirements for, and design of, a photographic subsystem.

The earliest feasible opportunity for another mission to Venus is 1970. An attractive possibility for this opportunity is a flyby mission with a gravity assist at Venus that will also provide a Mercury flyby.<sup>9</sup> This will provide a dual payoff on the TV experiment since any space photography of Mercury is guaranteed to be exciting. This mission could be accomplished using the so-called "spare parts" Mariner '69 spacecraft launched on an Atlas/Centaur. Because of the short time available, probes would not be considered for this mission. Radiometer and spectrometer instrumentation would be carried on the flyby spacecraft. The TV imagery should be obtained in the visible and near ultraviolet at Venus since there are reports of cloud motion recorded in the UV from earth.

In 1972 the Titan III-C orbiter program should place the first U.S. spacecraft in orbit about Venus. The prime orbital experiment should be TV, with selected filters, to map cloud morphology and motion and make a concentrated search over the entire planet for visible access to the surface. An



imaging radar system would guarantee low resolution pictures of the surface in the microwave portion of the spectrum. A single atmospheric probe could be carried to measure atmospheric thermodynamic properties in the region above 26 km as well as below. This thermodynamic data would be used for the design of meteorological balloons which will be delivered during later manned flyby missions.

1973 is apparently the last favorable opportunity for a Venus gravity assist to Mercury until 1982 (this will be discussed in the next section on Mercury). In view of this, a second surface mission is suggested using the '69 Mariner class spacecraft and Titan III-C launch vehicle. It will be carried as the prime spacecraft experiment for Mercury. Some pictures will be taken of Venus, although they may be anti-climactic after the 1972 orbiter mission. The prime Venus experiment will be a survivable surface impacting probe<sup>(10)</sup>. A probe weighing in excess of 600 lbs can be delivered with an 800 lb flyby spacecraft by the Titan III-C. This probe would survive at least one hour on the ground and relay data to the flyby bus on landing dynamics, light level, temperature, pressure and wind velocity. The main function of this lander probe is to begin a survey of surface conditions to determine whether more sophisticated soft landing probes have any role in the future exploration of Venus.

The 1975 opportunity should capitalize on previous surface imagery and Venus lander technology to launch two orbiter flights with impacting lander capsules. Because of the dense atmosphere, landing velocities can be less than 100 feet/sec with nothing more than vehicle aerobraking. The earlier lander payload can be supplemented by a panoramic TV scan system relaying data to the orbiter. Two landers at different points should provide the basis for interesting data comparisons. This mission should provide the design basis for a possible second generation surface lander. The orbital mission will include TV cloud photography, microwave imagery of the surface, and possible high resolution film or dielectric tape photography. Improvements in the orbiter communication system should allow a greater data return compared to the 1972 mission.

A final orbital mission in 1977 should attempt to complete the cloud and surface mapping to minimize this function on the manned flyby mission. Multiple probes launched into the atmosphere at different points should provide a glimpse of the global weather patterns. Coupled with cloud photography and surface data, simple circulation and atmospheric density models should be constructed to aid in mission planning for subsequent weather balloon deployment.

The increased exploration objectives of the 1975 and 1977 missions probably would require a vehicle with a payload capability between that of the Titan III C and the Saturn V. The principal weight increase would come from the impacting lander capsules, and the need for either a high resolution optical or radar imaging system.

The first manned flyby mission passes Venus in 1979 and again in 1980. A prime objective of this mission is to increase the understanding of the atmospheric circulation. A major experiment will be the deployment of multiple weather balloons which will record local pressure and temperature and be tracked from an orbital probe. The balloons will be set to float at several different altitudes based on earlier thermodynamic data. Several improved first generation lander probes may also be launched from the manned spacecraft. Also, if surface photography from orbit has been precluded by unbroken cloud cover, several Ranger-type TV probes might be used to photograph the surface from below the cloud layer.

In 1981 and 1983, the second manned flyby mission makes its two passes by Venus. The prime objective is the search for life in the Venus atmosphere and possibly on its surface. The major atmospheric probe might be a so-called Buoyant Venus Station (11) or BVS, which is a several thousand pound floating experiment station. Data from the meteorological balloon mission will be used to predict the course of this probe and to select an optimum deployment point. Key experiments will include detailed composition analyses of the atmosphere at various points and the search for life forms in the temperate regions of the atmosphere. A TV microscope with data relayed through an orbital probe link either to earth or the manned spacecraft could be used for this experiment. Second generation surface landers may be employed, possibly emphasizing the search for life on the ground.

The exploration of Venus in the 80's would involve manned orbital missions to obtain high resolution imagery of the surface and a more detailed exploration of the atmosphere. At this time, a manned landing on Venus appears to be unfeasible due to the high surface temperature. A Venus orbiting mission in the early 80's would serve to pace the development in the 70's of a high energy space storable propulsion system. This system would provide the capability of sending relatively large unmanned probes to the outer planets when used as an out-of-orbit propulsion system and would also provide the capability for manned orbital missions to Mars.

#### MERCURY

Mercury is extremely difficult to observe with earth-based optical telescopes because it is an inner planet close to the sun. Its small size and large distance from earth have

also made radio observations difficult. Only recently have radar astronomers shown that Mercury's rotation rate is not sun-synchronous as the optical astronomers had long thought.

Optical imagery is probably the most interesting experiment to perform on a space mission to Mercury. This would provide data on surface topography and morphology, as well as measure the optical diameter so that the planet density could be determined. Since the moon and Mercury are of comparable size but have quite different surface heating rates, comparison of the morphology of the two bodies might lead to some insight into the visible effects of temperature on planetary surfaces. ~~As the planet passes between the spacecraft and earth,~~ a radio wave occultation experiment could determine atmospheric surface pressure and detect a possible ionosphere. Due to the position of the earth relative to the Sun and Mercury at encounter, a compromise will have to be made between the extent of photographic coverage and the occultation experiment.

Direct flights to Mercury are available every year with a  $C_3$  of approximately  $41 \text{ km}^2/\text{sec}^2$ , with little year-to-year variation. (12) Neither the Atlas/Centaur nor the Titan III-C is capable of launching a spacecraft in the Mariner '69 weight class on such a mission. The class of launch vehicles which could provide the necessary  $C_3$  for a Mariner '69 spacecraft is illustrated by the Titan III-C(1207). Venus swingby missions are available which in certain years offer a considerable savings in terms of  $C_3$ . Two of the most favorable Venus swingby opportunities occur in 1970 and 1973. (13,14) The trip time to Mercury is approximately 150 days and the  $C_3$ 's lie between  $12$  and  $20 \text{ km}^2/\text{sec}^2$ , which is within the capability of the Atlas/Centaur. Although swingby opportunities occur roughly every 19 months, the problems associated with the low periastron altitude at Venus are such that opportunities in 1972, 1975, 1977, and 1978 are not now thought to be usable. In the 80's and 90's several low energy opportunities are available with more acceptable Venus periastron altitudes and trip times of approximately 300 days. The tradeoffs between guidance accuracy, propulsive maneuvers, and geometry for the late 70's opportunities have not been thoroughly explored and the above view may change as the result of more study.

Swingby missions are shown in Figure 1 for 1970 and 1973 to capitalize on the favorable opportunity for Mercury and on the advantage of visiting two planets with a single spacecraft. These missions have been discussed in part in the Venus section of this Memorandum. Different surface areas of Mercury could be photographed on each mission.

Figure 1 does not indicate flights to Mercury beyond 1973, since the next mission should probably be an orbiter. Retrobraking a spacecraft into Mercury orbit is extremely costly in propulsion, and a determination of the value of this mission should be postponed until after the first successful flyby.

#### JUPITER

Jupiter is the brightest source of decametric radiation in the sky, with the possible exception of the disturbed sun. Its radio emission is related to the planet temperature, charged particle and magnetic field properties in a manner which is not completely understood. Hydrogen has been identified as the major constituent of the planet, with ammonia and methane being minor components. How these components are distributed in the atmosphere and solid body of the planet has not been determined experimentally. Perhaps Jupiter's most well known puzzle is the Red Spot which has intrigued scientists since it was first observed.

The possibility of sending probes to Jupiter and beyond may require advances in technology in several areas. These include non-solar power sources, reliability consistent with 1.5-10 year mission times, and long range communication systems.

Figure 1 shows Jupiter probe flights in 1974 and 1975 and the "Grand Tour" opportunities in 1977 and 1978. (15) The 1974 and 1975 flights are precursors to the "Grand Tour" missions and represent a new class of spacecraft with major advancements in the power and communication subsystems. Spacecraft in the 600 lbs weight category using an Atlas/Centaur with a kick stage for the launch vehicle are under study. The experiment payload of this flyby spacecraft would emphasize interplanetary and planetary particle and field measurements. The meteoroid environment in the asteroid belt between Mars and Jupiter is also of scientific interest and would affect the spacecraft design for subsequent missions to the major planets.

The two "Grand Tour" missions to the major planets in 1977 and 1978 use a Jupiter gravity assist to pass by Saturn and Uranus and finally reach Neptune approximately 8 to 9 years after earth departure. Besides visiting four planets on a single flight, the normal trip time to Neptune is diminished by about a factor of 3. This attractive opportunity is not known to be repeated within the next 100 years. (16)

By the time of the 1977 and 1978 flights, some improvements in the spacecraft communications and other subsystems might raise the total spacecraft weight to around 1000 lbs and would require a Titan III-C/Centaur launch vehicle. Rather than develop two new launch vehicles for this program,



it is suggested that the Titan III-C/Centaur also be used for the Galactic Jupiter Probe missions in 1974 and 1975. This extra booster capability could be used to advantage to shorten the trip time for the first Jupiter flights.

#### ASTEROIDS AND COMETS

Several flyby mission opportunities are available in the late 1970's and early 1980's to reach comets and asteroids (15). These would employ Mariner '69 spacecraft technology, although improvements would have to be made in the scan platform to counter the high closure rates. TV would be a prime experiment. The Titan/Centaur would serve as the launch vehicle for the opportunities in the 1970's.

#### SUMMARY

The planetary program presented is a way of obtaining substantial scientific data on the nature and structure of the solar system during the 70's, of keeping the option of manned planetary exploration in the late 70's, and of providing for continued unmanned exploration of the outer planets. It is, as of December, 1967, feasible and meaningful. The particular program depends on certain critical FY 69 thru FY 71 funding decisions. As these decisions are made, it will be necessary to introduce variations in the follow-on program. As more technical work is completed, better means to accomplish the missions may be found. The exploration logic is somewhat more durable and provides a basis for structuring a planetary program as future decisions are taken by NASA.

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Attachment

